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NOTE

EUROPEAN FROGBIT (*HYDROCHARIS MORSUS-RANAE*) IN THE CHAMPLAIN/ADIRONDACK REGION: RECENT INFERENCES

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As part of its north-south movement following introduction to Canada, *Hydrocharis morsus-ranae* L. (Hydrocharitaceae) has recently become established in slow-moving waters of the Champlain/Adirondack region of the northeastern US. The species is present on both the New York and Vermont shores of Lake Champlain and, so far, at a single location in the interior of the Adirondack Park. The southernmost Champlain/Adirondack occurrence is in the Champlain Canal south of Whitehall, NY (L. Eichler, Darrin Freshwater Institute, pers. comm.), within 25 miles of the Hudson River watershed—a population first recorded around 2006. Entry into the Hudson watershed, whether from the canal or Adirondack headwaters, has the potential to increase the spread of European frogbit well beyond the handful of spot occurrences currently recorded in the rest of the Northeast. The objective of this note is to summarize findings derived from recent student-driven research conducted on the status and biology of *H. morsus-ranae* in the Champlain/Adirondack region.

Much of what we know about *Hydrocharis morsus-ranae* in North America is based on studies in Canada by Catling and collaborators (Catling and Dore 1982; Catling et al. 1988; Catling, et al. 2003; Catling and Porebski 1995) and on more recent work, by Zhu, in the Finger Lakes (NY) region (Zhu et al. 2008, 2014); yet, little is known about the status and biology of the species in the Champlain/Adirondack region. Abundant evidence exists, however, that the species is currently at nuisance levels in some areas of Lake Champlain. For example, the Lewis Creek Association in 2010 employed 2497 field-hours to remove (by hand) 28 tons of *H. morsus-ranae* (Illick 2013) from Town Farm Bay (Charlotte, VT). This sort of biomass dominance is not uncommon where invasions occur; and this floating-leaved species easily monopolizes the water surface, choking out submerged plants in shallow waters while reducing gas exchange and light penetration to the water column (Marsden and Hauser 2009; Zhu et al. 2014).

Reproductive biology. Clonal reproduction in *Hydrocharis morsus-ranae* is known to be vigorous and likely confers much of the invasive potential of the species. The contributions of sexual reproduction, on the other hand, have not been extensively studied and remain poorly understood. Although dioecy is the most commonly cited reproductive condition for *H. morsus-ranae*, research done in Ontario showed that a small percentage (5–10%) of the population in Lake Erie is monoecious (Scribailo and Posluszny 1984). Although populations of *H. morsus-ranae* in dense shade may forgo flowering entirely (the aforementioned population in the Adirondack Mountains did not flower in three years of observation; Langdon, pers. obs.), populations in Lake Champlain have flowered profusely every year.

In the first breeding system survey of *Hydrocharis morsus-ranae* in Lake Champlain, presented here, data were collected from populations on the western shore: Point Au Roche State Park, Ausable Point Wetland Management Area, and the mouth of the Little Chazy River. Populations were surveyed for breeding system and sexual status (dioecious/male, dioecious/female, or monoecious), as well as natural fruit/seed set. Across the three sites, the 1400 flowers evaluated revealed staminate flowers outnumbered pistillate flowers by 3:1, with two populations exceeding 4:1.

Hundreds of genets were evaluated for breeding system status, with care taken to avoid breakage of stolons, and the populations

were found to be almost entirely dioecious. In fact, just a single genet was monoecious, with that individual consisting of six pistillate plantlets and one staminate plantlet. This suggests that most pollination events will be the result of outcrossing.

Because no natural fruit set was recorded during the surveys, staminate and pistillate plantlets were moved to greenhouse aquaria and hand pollinations were performed. Of 48 crosses, 15 (31%) led to fruit formation, suggesting that sexual reproduction is possible, and likely occurring, in Lake Champlain. A fully clonal population of *Hydrocharis morsus-ranae* could be "super-adapted" for invasion, but a common (identical) genetic make-up could mean all plants might be equally susceptible to certain control methods. Unfortunately, the plants in the local infestation appeared to possess the ability to adapt and evolve via the genetic variability achieved through sexual reproduction, as well as to infrequently establish new sexual populations with individual self-fertile colonizers.

Effects on natural communities. In a study examining the effects of *Hydrocharis morsus-ranae* on native macrophytes, Catling et al. (1988) reported a decline in native aquatic species in the presence of *H. morsus-ranae*, and a consequent recovery of native taxa when the invader was removed.

The response of *Hydrocharis morsus-ranae* to eradication in the first known invasion site in the Adirondacks, a population near Lampson Falls in the Grasse River Wild Forest (Clare, NY), showed that low numbers of *H. morsus-ranae* plantlets continued to be recruited from turions in the first year after removal, but at levels reduced enough to initiate the rapid recovery of native taxa (Langdon 2007). Surveys in subsequent years revealed continued recovery of native aquatic macrophytes but, also, continuous appearance of *H. morsus-ranae* individuals—possibly from the turion bank. These findings thus confirm expectations that, even in small and remote areas, management of this invader requires diligence and vigilance.

Long-term plant community analyses in Lake Champlain's 267 ha Ausable Marsh (Peru, NY) by Shearman (2011) noted localized dominance of *Hydrocharis morsus-ranae* and quantified its influence on co-occurring native aquatic plant species. A multiple regression analysis of *H. morsus-ranae* on all other species revealed a relationship between it and *Elodea canadensis* Michx., with the two species often trading dominance. An especially intriguing

observation was that a set of submerged native macrophytes [*Ceratophyllum demersum* L., *Myriophyllum sibiricum* Kom., *Potamogeton hillii* Morong, *P. zosteriformis* Fernald, and *Spirodela polyrhiza* (L.) Schleid.] was actually more abundant in the presence of *H. morsus-ranae* than with *E. canadensis.* Interestingly, *E. canadensis* is considered invasive outside of its native range and has allelopathic tendencies (Erhard and Gross 2006). In the post-invasion short term, perhaps *H. morsus-ranae* indirectly releases other submerged aquatic plants by first suppressing *E. canadensis*.

Over the long term, however, shifts in plant community composition due to high-density mats of *Hydrocharis morsus-ranae* could have cascading repercussions at higher trophic levels that are yet to be determined. Binggeli (2011) measured differences among Lake Champlain zooplankton and invertebrate communities collected in native versus invasive (including *H. morsus-ranae*) macrophyte beds and found that whether a species is an exotic invasive or not, is less critical than the growth habit it employs. Many more aquatic insects (numbers and taxa), for instance, use submerged/divided-leaved macrophytes than use floating-leaved species. Based on this finding, the presence of *H. morsus-ranae* has about the same effect on trophic interactions as the presence of natives such as *Nymphaea odorata* Aiton and *Nuphar variegata* Durand. In instances where *H. morsus-ranae* invades and out-competes submerged/divided-leaved species, however, we might expect communities to experience a consequent reduction in insect abundance and diversity, as well as in the fish populations that prey on them.

The future. In North America, and in its native range, *Hydrocharis morsus-ranae* cannot establish in fast-moving and highly dynamic waters (Toma 2013), which limits its niche to calm backwaters, shallow shorelines, and marshes and swamps. Our sense is that it is likely established in nearly every Lake Champlain habitat where it can grow. Moreover, evidence suggests that it is creeping into the mouths and lower reaches of many rivers and creeks that lead to the lake, as it has done on the Little Chazy River (Martine et al. 2009), Ausable River (Shearman 2011), and Lewis Creek (Illick 2013). The same dynamic waters that can limit its establishment can also disperse its propagules. It is not hard to imagine that propagules and plantlets will continue to move with the flow of water that leaves the southern end of Lake Champlain

through the Champlain Canal, connecting it with the Hudson River.

Where the species occurs in isolated small water bodies, such as at its initial entry into the Adirondacks and in similar incursions in northern Michigan (K. Kucher, Michigan Department of Natural Resources, pers. comm.), hand pulling has been proven effective. In larger water bodies, such as Lake Champlain and Lake Erie, where *Hydrocharis morsus-ranae* is too abundant and too dispersed to eradicate, the best we might hope to do is keep it from moving further—a conclusion also made by Zhu et al. (2008) when considering the imminent arrival of the species in the Finger Lakes and subsequent access to the Susquehanna watershed.

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